A Case Study of the Environmental Experience of a Hospitalized Newborn Infant with a Complex Congenital Heart Defect

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Cognitive, social, emotional, behavioral, and motor delays pose a significant concern for infants born with congenital heart disease (Hirose, Ichida, & Oshima, 2007; Snookes et al., 2010). The etiology of these neurodevelopmental delays is multi-factorial and includes early, invasive surgery (Hülser et al., 2007; Marino et al., 2012; Snookes et al., 2010), pre- and post-surgical cerebral injury (Andropoulos et al., 2010), and parental distress (Hülser et al., 2007; McCusker et al., 2007). However, the highly technological physical environment of intensive care units may also contribute to these adverse outcomes through chronic activation of infant stress responses that alter brain function and structure and are associated with neurodevelopmental impairments in similar high-risk populations (McEwen & Gianaros, 2010).

The effect of the physical environment on infant neurodevelopment has been examined in premature infants cared for in neonatal intensive care units (NICU). Environmental factors associated with adverse outcomes in premature infants include excessive noise and light as well as interrupted sleep resulting in delayed growth and altered brain development (Peng et al., 2011; Smith et al., 2011). Similar conditions of light, noise, and disrupted sleep may be present in cardiac specialty units, potentially affecting neurodevelopmental outcomes in newborns with cardiac disease. Until relatively recently, all newborns with compromised health conditions were cared for in NICUs, which provide care focused exclusively on newborns. Cardiothoracic intensive care units (CTICU) and cardiac step-down units (SDU) are recent innovations in care delivery in hospitals across the country. Newborns with cardiac conditions are now cared for in these units both before and after surgery and with a wide-range of age groups, from birth through middle-age and beyond. Considering the age spectrum, the environment in which care is provided may be affected. Environmental stressors and tolerance levels would vary depending on the patient's developmental level, cardiac condition, and recovery stage. The environment of these specialized cardiac units may be more similar to a pediatric or adult intensive care unit than a newborn-focused NICU. The physical environment of neonates with congenital heart disease cared for in cardiac specialty units has not been described.

The purpose of this case study was to examine the environmental experience of the newborn infant with complex congenital heart disease undergoing an invasive surgical procedure within the first month of life. Measurements of illumination, sound levels, and sleep were recorded on one infant for two days in the CTICU and two days in the cardiac SDU.

Case Study

This case study was part of a larger study describing the environmental experience of newborns hospitalized for treatment of complex congenital heart disease. The infant's mother provided written informed consent. The case infant was male, born at 39.43 weeks, weighed 3709 grams, and had APGARS of 6 at one minute and 9 at five minutes following vaginal delivery to a 20 year old, G1P1 unmarried mother. At delivery, the infant was pale with a peripheral oxygen saturation of 84% on room air. Infant was initially placed on continuous positive airway pressure and then nasal cannula for transport to a large Midwestern Children's Hospital with an arrival condition of stable, cyanotic, and alert. The infant was diagnosed with severe Tetralogy of Fallot *(*ToF) with pulmonary atresia and patent ductus arteriosus (PDA). ToF is one of the most common cyanotic heart defects involving four structural heart anomalies which commonly present together. The four malformations consist of: (1) a large ventricular septal defect (VSD); (2) an overriding aorta, arising from both the left and right ventricles and positioned above the VSD; (3) pulmonary stenosis, a narrowing of the pulmonary valve creating an obstruction of blood flow from the right ventricle to the pulmonary artery (the pulmonary valve in this infant was severely hypoplastic, significantly restricting blood flow from the right ventricle to the lungs); and (4) right ventricular hypertrophy, i.e., a thickening of the muscle wall of the right ventricle as a result of the right ventricle pumping at high pressure. This infant also had a patent ductus arteriosus (PDA). The ductus arteriosus connects two major arteries, the aorta and the pulmonary artery, and serves as an essential component of the fetal blood circulation. As part of the typical circulatory changes following birth, the ductus arteriosus pathway closes within minutes to a few days following birth. When the ductus arteriosus remains patent, continued blood flow through the PDA allows oxygen-rich blood from the aorta to mix with oxygen-depleted blood from the pulmonary artery, placing a heavy strain on the heart and increasing blood pressure in the pulmonary vessels.

In the absence of symptoms or significant cyanosis, surgery for ToF is usually performed within the first six months of life (Hoffman, 2009). Due to the case infant's cyanotic presentation and low oxygen saturation levels immediately following delivery, early intervention was required. The infant underwent a modified Blalock Taussig shunt (BT shunt) at 10 days of age. The BT shunt (a tiny tube made of Gore-Tex) created a connection between the innominate artery (arising from the aorta) and the pulmonary artery, allowing enhanced pulmonary blood flow. In addition, the PDA was surgically closed by tying off the vessel with a synthetic ligature. The infant experienced supraventricular tachycardia during the procedure which was successfully treated. In the early post-operative period, the infant experienced one episode of prolonged apnea secondary to sedation, which responded to manual bag and mask ventilation, followed by delivery of oxygen via nasal cannula. The remainder of the infant's post-operative course was unremarkable. He was monitored in the CTICU for 74 hours, continued recovery in the step-down unit, and was discharged at 16 days of age.

Measurement/ Procedure

Data collection began the day following surgery (Post-op Day 1). At each of the four data collection time periods, noise, light, and sleep were measured. Day 1 and Day 2 data collections were conducted in a 10-bed, open bay area of the 20-bed CTICU with privacy curtain partitions separating each bed. Day 3 and Day 4 data collections were conducted in one of the 24 private rooms making up the cardiac step-down unit (SDU). Data collection on post-operative Day 1 was a 24-hour segment from 0700 to 0700. On Day 2, the infant was unexpectedly scheduled to transfer to the SDU the following day. Upon receiving this information, data collection was begun at 2123 and ended at 1232 the following day, prior to transfer, for a total of 15 hours 9 minutes. Data collection on Day 3 was a 24-hour segment from 0700 to 0700 on the infant's first full day in the SDU. Data collection on Day 4 was a 24-hour segment from 0700 to 0700 on the second full day in the SDU. The infant was discharged 5 hours after completion of Day 4 data collection.

Noise levels were measured using an Etymotic Research Wearable and Programmable Personal Noise Dosimeter Model ER-200DW7 with Data Logging (Etymotic Research, Inc., Elk Grove Village, IL). Noise was measured in equivalent sound level (Leq) in A-weighted dB with values obtained every 0.22 seconds, then summed and recorded in 3.75 minute intervals (16 times per hour). A-weighted decibels (dBA) measures the volume or intensity of sound as an expression of the relative loudness of sounds in air as perceived by the human ear. The data accuracy of the noise docimeter is ± 2.5 dBA. The microphone was secured to the infant's bed within 30 cm of the newborn's ear. Four measures were used: (1) mean noise levels in dBA for each day's observation, (2) hourly means in dBA (Leq 50), (3) percentage of the total hours each day in which the infant was exposed to more than 6 minutes of noise greater than 55 dBA, i.e. an increase in noise of 10% over the recommended levels (L_{10} 55), (4) numbers of single events in which noise was greater than 70dBA (L_{max} 70).

Light exposure was measured using a Digital Light Meter w/Data Logging SD Card Model DLM112SD (General Tools and Instruments, New York, NY), which calculates the luminous intensity of the light falling on a specific object. Luminous intensity is measured and reported in lux and represents the intensity of light as perceived by the human eye measured in lumens per square meter (lm/m^2). The accuracy of the lux meter is ± 4% of full-scale reading. Infant light exposure was measured at 6-second intervals and averaged for each hour. The sensor was secured to the bed of the infant within 20 cm of the head. Primary measures of light were mean (SD) for each day as well as minimum and maximum levels reached per hour. The presence of cycled lighting in the CTICU and SDU was also measured. Cycled lighting refers to the provision of light exposure supportive of circadian entraining (Mirmiran & Ariagno, 2000), i.e., approximately 12 hours of light on and 12 hours of light off to mimic natural light-dark cycles (Rivkees, Mayes, Jacobs & Gross, 2004).

Sleep was measured using actigraphy, which is a commonly used and reliable, non-invasive method to assess sleep-wake cycles (Sadeh, 2011). Continuous 24-hour actigraph recordings were obtained using an ActiWatch2 activity monitor (Philips Healthcare, Bend OR). The monitor, about the size of a small wristwatch, was placed in a cloth sleeve and positioned midway between the infant's foot and knee. Infant activity was counted in 15 second epochs. Each epoch is scored as awake or sleep based on comparing activity counts to the threshold value set by the researcher. If the number of counts exceeds the threshold, the epoch is counted as awake; if the count is equal to or below the threshold, the epoch is counted as sleep. Consistent with the literature, we set the threshold at 20 activity counts per 15 second epoch, i.e. 80 per minute (So, et al., 2005). The observation period was separated into wake times and rest times. During wake times, the infant is expected to be awake, such as feeding and patient care times; during rest times, the infant would be expected to be or could be sleeping. To describe potential effects of the environment on sleep in these infants, all calculations of sleep were obtained during the rest times. We measured sleep efficiency (i.e., the percentage of time the infant is asleep during rest times) over each day's observation as well as during the 12 hour day and 12 hour night time periods. Sleep efficiency for healthy newborn infants has not been reported; healthy adults have a sleep efficiency of 92% (Calogiuri et al., 2011). We also calculated percentage of sleep for the entire observation periods. Newborns generally sleep for about 70% of the time in a 24 hour period [American Academy of Pediatrics (AAP), 2013]. Additional variables were maximum duration of sleep epochs and number of awakenings during rest times. Parents recorded sleep, feedings, holding, and patient care activities (e.g. dressing changes) in a diary divided into 15-minute epochs. The diary was used to corroborate activity between the actigraphy data and electronic nursing records to determine infant rest times.

Analysis and Findings

Noise

Mean daily noise is reported in Table 1; hourly noise is graphically presented in Figure 1. For this infant, mean (SD) daily noise exposure was 20.28 (27.75) dBA on Day 1 (in the CTICU). However, in 16 of 24 of those hours (66.7%), the infant was exposed to more than 6 minutes of noise greater than 55 dBA and 23 episodes of acute noise events > 70 dBA. On Day 2 (in the CTICU), mean (SD) daily noise exposure was 58.94 (7.38). Every hour of the Day 2 observation had noise levels greater than 55 dBA, making up 76.5% minutes of that 15 hour observation. On this day, the infant also experienced 30 episodes of acute noise events > 70 dBA. On Day 3 (in the SDU), mean (SD) daily noise exposure was 39.60 (23.24). During 14 of 24 hours (58%), the infant was exposed to more than 6 minutes of noise greater than 55 dBA and 34 episodes of acute noise events > 70 dBA. On Day 4 (in the SDU), mean (SD) daily noise exposure was 38.64 (24.27). Similar to Day 3, during 14 of 24 hours (58%), the infant was exposed to more than 6 minutes of noise greater than 55 dBA and 23 episodes of acute noise events > 70 dBA.

Light

The recommended light level for neonatal intensive care units is < 646 lux (AAP, 2002). Average daily LUX exposure is reported in Table 2. For this infant, Day 1 (CTICU) data reflected light exposure to 1582 lux in 6 separate hourly epochs ranging from 2 to 54 minutes in duration, between the hours of 0800 and 1700. The remaining 18 hours reflected illumination levels remaining within the recommended limits. Day 2 (CTICU) data reflected a 1-second occurrence of 2551 lux in the 0300 hour which correlated with a parent diary log of a surgical dressing change. This 1-second spike was the only recorded level of excessive light exposure during the 15 hours of observation for this day. Day 3 (SDU) data reflected light exposure to 5651 lux in 10 separate hourly blocks of time ranging from 12 seconds to 59.7 minutes in duration, between the hours of 0800 and 2000. The remaining 14 hours showed light levels which remained in the recommended limits. Day 4 (SDU) data reflected rates reaching up to 5608 lux in 7 separate hourly blocks of time ranging from 2 to 59.7 minutes in duration, between the hours of 1200 and 2100 with the additional 17 hours staying within the recommended light limits. See Figure 2 for hourly maximum LUX exposure and Table 3 for hours in which LUX guidelines were exceeded, including duration in minutes. All but one second of the elevated lighting occurrences transpired between 0800 and 2100 hours indicating the presence of cycled lighting.

Sleep

Minutes in sleep by day of observation is reported in Table 4 and in Figure 3. During the 24 hour Day 1 observation (CTICU), 17 hours were identified as rest time during which sleep efficiency was 83.0% with a total of 183 separate awakenings. The most time spent sleeping was between 1900 and 2300 (212 minutes), and the least amount of time sleeping was between 2300 and 0300 (105 minutes). The longest sustained sleep without waking was 87.75 minutes, and the infant slept 59% of the 24-hour period. During the 15-hour Day 2 observation (CTICU), 9 hours were identified as rest time during which sleep efficiency was 80.4% with a total of 104 awakenings. The most time sleeping was between 0500 and 0900 (150 minutes), and the least amount of sleeping was between 2100 and 0100 (53 minutes). The longest sustained sleep without waking was 31.5 minutes, and the infant slept for 45% of the 15-hour period. During the 24-hour Day 3 observation (SDU), 14.5 hours were identified as rest time during which sleep efficiency was 81.1% with a total of 184 awakenings. The most time sleeping was between 0700 and 1100 and between 1900 and 2300 (136 minutes each), and the least amount of sleeping was between 1500 and 1900 (91 minutes). The longest sustained sleep without waking was 49.5 minutes, and the infant slept for 49% of the 24 hour period. During the 24-hour Day 4 observation (SDU), 15.5 hours were identified as rest time during which sleep efficiency was 73.9% with a total of 178 awakenings. The most time sleeping was between 0700 and 1100 (147 minutes), and the least amount of time sleeping was between 1100 and 1500 (90 minutes). The longest sustained sleep without waking was 24.75 minutes, and the infant slept for 48% of the 24-hour period. The average sleep efficiency for the 4 days of observation was 79.6% with an average number of wakings per hour of 11.62. The day/night sleeping percentages were Day 1: 53.5/64.1; Day 2: 49.4/61.0; Day 3: 48.4/51.0; and Day 4: 45.8/49.6.

Discussion

In this case study, we measured noise, light, and sleep experienced in two cardiac care units by a full-term infant following palliative surgery for Tetralogy of Fallot. We found levels of noise and light higher than recommended guidelines and poor sleep efficiency with multiple awakenings.

Noise

On average, the daily noise exposure remained below the recommended guideline of 45 dBA except for Day 2 where the noise exceeded the recommended average reaching a mean of 58.94 dBA. However, in contrast to daily averages, the infant was exposed every day to significant intermittent periods of excessive noise with 59 of 87 hours reporting more than 6 minutes of elevated noise exposure greater than 55 dBA, and 110 episodes of acute noise events greater than 70 dBA. Increases in noise intensity in the CTICU and SDU could be the result of equipment alarms, hospital announcements, codes, emergent care, patient care by healthcare providers, room placement, and room partition material.

Noise levels in pediatric ICUs are known to be higher than established guidelines (Al-Samsam & Cullen, 2005; Lasky & Williams, 2009; Salavitabar et al. 2010; Williams et al., 2007). Both ambient and intermittent noise levels elicit physiologic changes in neonates, including increases in heart rate, increases in respiratory rate, increases in blood pressure, and decreases in oxygen saturation (Slevin et al., 2000; Morris et al., 2000; Zahr & Balian, 1995). Preterm infant exposure to continuous noise in the NICU environment may be correlated with adverse affects on infant growth and development, including hearing loss, sleep disturbances, hypoxemia, increased stress, and disorganized behavioral states such as fussing, hypo- and hyper-alertness, grimacing, gaze aversion, and staring (Holditch-Davis & Blackburn, 2007; Peng et al., 2011). Our findings suggest that the amount of noise experienced by the infant recovering from cardiac surgery exceeds the recommended noise exposure for neonatal care. Although little is known about effects of noise exposure on development in infants with complex congenital heart disease, these findings are of concern and suggest the need for further investigation.

Light

The post-surgery infant in this study was exposed to inappropriate light levels that were at least 2.2 times higher than recommended. The discrete increases in light intensity in the CTICU and SDU were likely the result of focused patient care requiring higher light intensity, such as patient and surgical site assessments. The frequency and duration of excessive light exposure was somewhat higher in the SDU than in the CTICU. Intuitively, it seems that higher acuity patients would require higher light intensity. However, that was not the case with this infant. In the CTICU, a high acuity unit, the staff closely monitored the infant for the hours immediately following surgery. This monitoring occurred in the open bay area of the 20-bed CTICU with privacy curtain partitions separating each Giraffe radiant warmer bed. The Giraffe beds were specifically designed for a neonatal intensive care environment with lighting features included in the structure to minimize high intensity light exposure by setting the maximum intensity to 2000 lux, appropriate for procedures such as suture removal. In addition, the bedspace of this infant was located on the northwest side of the unit with a window about half the size of the windows in the SDU rooms. Ambient outside light admitted to the room would be dependent on the window shade position at the time of collection. The infant was moved to an open neonate crib and transferred to a SDU room located on the south side of the unit, thus admitting more ambient light when compared to the CTICU. The private rooms of the SDU have large windows, and overhead room lighting includes an examination option. Considering the frequency of excessive light levels in the SDU, the examination light was likely used to perform patient assessment or patient care by healthcare providers, and the window shade position most likely remained elevated.

Our findings also suggest that cycled lighting is currently used in these cardiac specialty units: all lux exposures exceeding recommended guidelines primarily occurred during daytime hours. Cycled lighting is recommended to promote the development of sleep organization through the exposure of low-intensity cycled lighting, from sunrise to sunset (Mirmiran & Ariagno, 2000; Rivkees et al., 2004). In studies involving premature infants, the absence of regular light-dark cycles as well as inappropriate levels of light in the NICU environment adversely impacted endocrine function, sleep rhythms (Fielder & Mosely, 2000), state organization, cardiovascular function, and behavioral development in the premature infant population (VandenBerg, 2007), who are already physiologically compromised and fragile. The information gained from our study provides initial data to suggest that environmental lighting is an area which requires additional investigation to examine potential effects on development in this high-risk neonatal population.

Sleep

The infant in this study was exposed to considerable levels of environmental stimulation from noise, light, and patient care ultimately causing extensive sleep interruptions. For each of the 4 observation days, infants experienced awakenings between 104 and 184 separate times. In addition, the highest percentage of time spent sleeping in a 24 hour day was 59%. The American Academy of Pediatrics reports that healthy newborns sleep a total of 960-1020 minutes or approximately 70% of a full day (AAP, 2013). Therefore even the highest amount of sleep obtained by the study infant following surgery fell significantly lower than the average healthy newborn.

Sleep is a vital necessity for brain development and healing, especially for infants who spend the majority of their first year of life in the state of sleeping (Bertelle et al., 2007; Ednick et al., 2009). In an intensive care unit setting, patients with compromised health conditions find the required level of sleep is especially elusive with unintentional yet repeated disruptions from noise, lighting, and intensive medical and nursing care (Peng et al., 2011). Disruptions in sleep organization can negatively affect infant brain development, immune system function, stress levels, and lead to serious behavioral and physiological alterations (Bertelle et al., 2007; Ednick et al., 2009; Peng et al, 2011). Research is critically needed to determine how to better support sleep in these vulnerable infants.

Limitations

This case study had several limitations. We reported on one infant's exposure to light, noise, and opportunities for sleep following surgical intervention for complex congenital heart disease in the CTICU and SDU. As such, these data cannot be used to generalize to all newborns cared for in cardiac specialty units. The study was descriptive in nature, and no definite cause and effect could be determined. Day 2 of the study was limited to 15 hours of observation due to the unusually rapid transition from the CTICU to the SDU as the infant progressed through recovery. Also, the activity diary may not have been adequately maintained by the parent(s) throughout the study. Finally, exclusions of at least one hour for each feeding for actigraphy analysis may have eliminated actual sleep time.

Implications for Nursing Practice

Nursing staff in the CTICU and SDU work with patients of all ages ranging from newborns to adults. Newborn infants with CCHD undergoing surgery within the first month of life are especially vulnerable to stressors that may affect developmental outcomes. Using the findings from this study, nurses could adjust their practice to reduce detrimental developmental effects of excessive light, noise, and sleep disruption on an individual level. Leadership from nurses in these specialty units is needed in order to champion strategies for implementing and maintaining appropriate developmental care practices that will reduce environmental stressors with this unique and fragile population (Torowicz, Lisanti, Rim, & Medoff-Cooper, 2012).

Conclusions

This study provides the first report of potential environmental stressors in newborn infants cared for in cardiac specialty units. These units are relatively new environments in which these critically ill newborn infants receive care. Excessive levels of light and noise as well as frequent interruptions for intensive medical and nursing care contribute to disorganized sleep and increased patient distress, and have the potential to impact subsequent neurodevelopment. Numerous studies have been performed measuring environmental influences on neonatal development in premature infants, resulting in policy and practice changes for improved infant outcomes. This single case study provides critical information for designing a future, larger study focused on identifying potentially adverse aspects of the intensive caregiving environment for newborn infants who have undergone neonatal cardiac surgery. Our findings suggest additional research with a larger sample is needed to describe potentially adverse environmental factors that may impact the development of these vulnerable infants with life-threatening cardiac disease.

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Table 1.

Descriptive Statistics and Number of Acute Noise Events by Day of Observation

	Mean	SD	Min	Max	# acute noise events
Day 1	20.28	27.75	0	82.75	23
Day 2	58.94	7.38	52	81.64	30
Day 3	39.60	23.24	0	81.86	34
Day 4	38.64	24.27	0	80.16	23

Table 2.

Average LUX Levels by Day

	Mean	SD	LUX minimum	LUX maximum
Day 1	362	240	0	1582
Day 2	154	126	0	2551
Day 3	436	742	0	5651
Day 4	307	849	0	5608

Note. Recommended maximum exposure for neonates is 646 LUX.

Table 3.

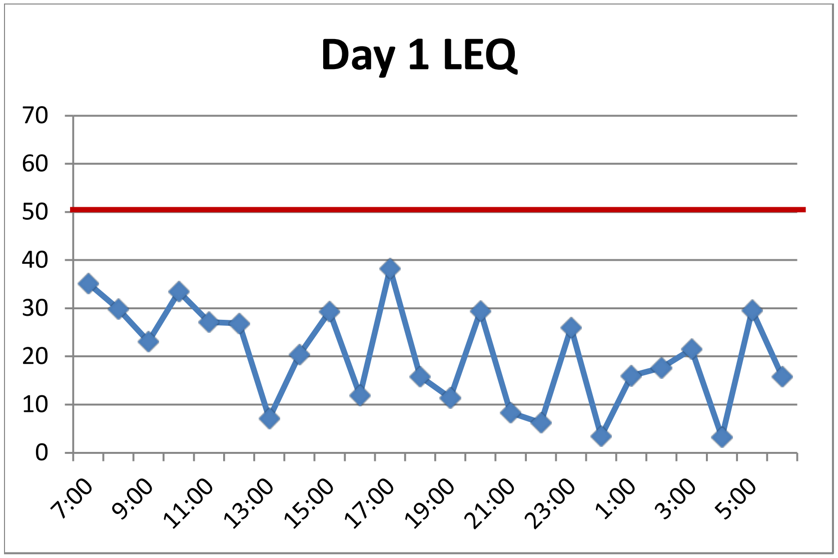
Value and Duration of Hourly LUX Levels Exceeding Recommendations

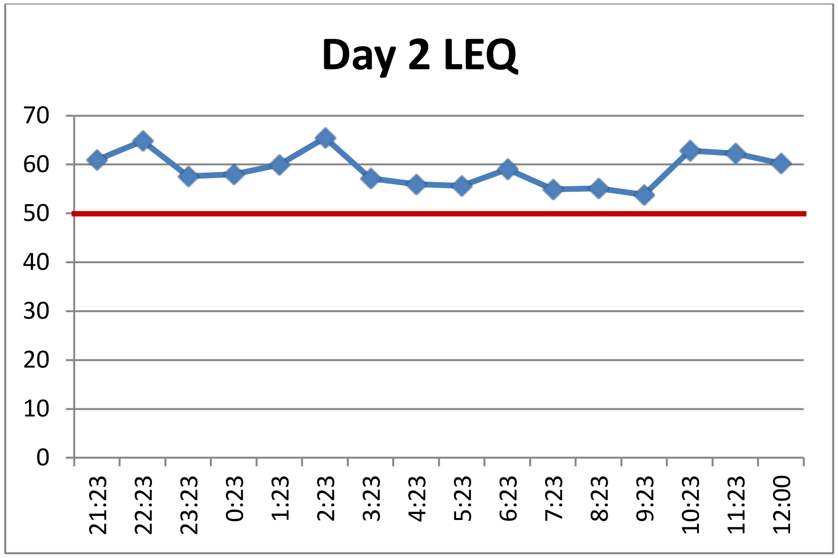
Day /Hour		Min	Max	Duration (minutes) exceeding recommended maximum (646 LUX)
Day 1	**0800**	**474**	**1055**	**54**
	0900	**205**	**1044**	**5**
	1000	**194**	**1582**	**12**
	1400	**301**	**657**	**2**
	1500	**248**	**678**	**23**
	1600	**291**	**678**	**16**
Day 2	**0300**	**0**	**2551**	**0.02**
Day 3	**0800**	**183**	**850**	**20**
	0900	**560**	**5651**	**59.7**
	1000	**0**	**5404**	**2**
	1200	**151**	**689**	**0.20**
	1300	**237**	**657**	**0.35**
	1400	**398**	**5102**	**47**
	1500	**140**	**1518**	**55**
	1600	**312**	**1044**	**34**
	1800	**0**	**3488**	**22**
	1900	**0**	**2855**	**16**
Day 4	**1200**	**22**	**5608**	**12**
	1300	**129**	**4370**	**59.70**
	1400	**0**	**2971**	**22**
	1500	**0**	**5328**	**3**
	1600	**0**	**3466**	**6**
	1700	**0**	**3488**	**9**
	2000	**0**	**5608**	**2**

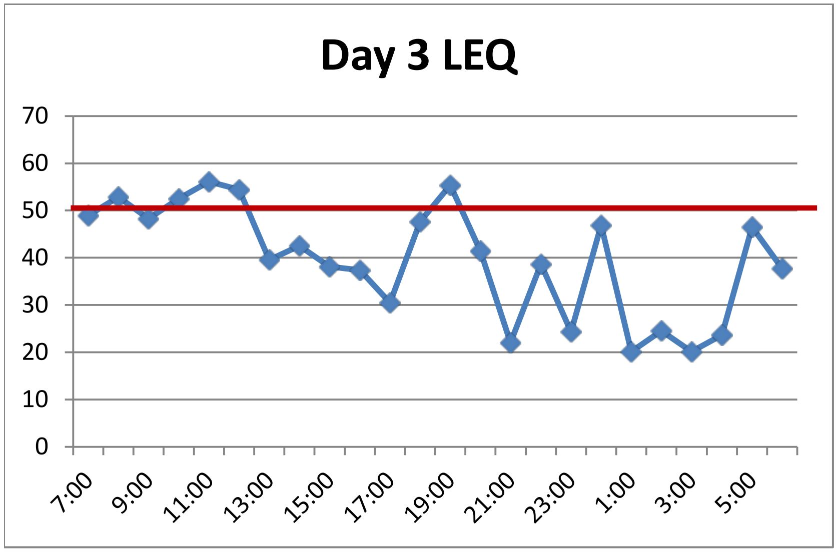
Table 4.

Minutes in Sleep by Day

	Hours of Rest	Minutes (%) in sleep			Sleep duration (minutes)		# Wakings
		Total	Day	Night	Average	Maximum	
Day 1	17	847 (58.8)	385.50 (53.5)	461.25 (64.1)	34.78	87.75	183
Day 2	9	434 (45.2)	177.75 (49.4)	256.25 (61.0)	19.15	31.50	104
Day 3	14.5	706 (49.0)	348.75 (48.4)	356.75 (51.0)	21.88	49.50	184
Day 4	15.5	687 (47.7)	330.00 (45.8)	357.00 (49.6)	16.63	24.75	178


Day 1 LEQ
70
60
50
40
30
20
10
0
7:00
9:00
11:00
13:00
15:00
17:00
19:00
21:00
23:00
1:00
3:00
5:00


Day 2 LEQ
70
60
50
40
30
20
10
0
21:23
22:23
23:23
0:23
1:23
2:23
3:23
4:23
5:23
6:23
7:23
8:23
9:23
10:23
11:23
12:00


Day 3 LEQ
70
60
50
40
30
20
10
0
7:00
9:00
11:00
13:00
15:00
17:00
19:00
21:00
23:00
1:00
3:00
5:00

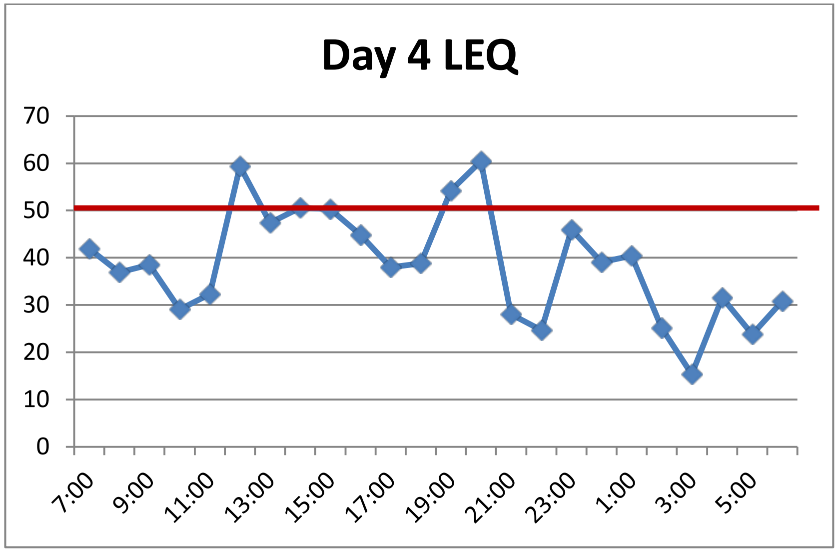

Day 4 LEQ
70
60
50
40
30
20
10
0
7:00
9:00
11:00
13:00
15:00
17:00
19:00
21:00
23:00
1:00
3:00
5:00

Figure 1. Hourly noise levels for the four days of observation. Red line indicates guideline for maximum exposure of an average of less than 50dB within one hour.

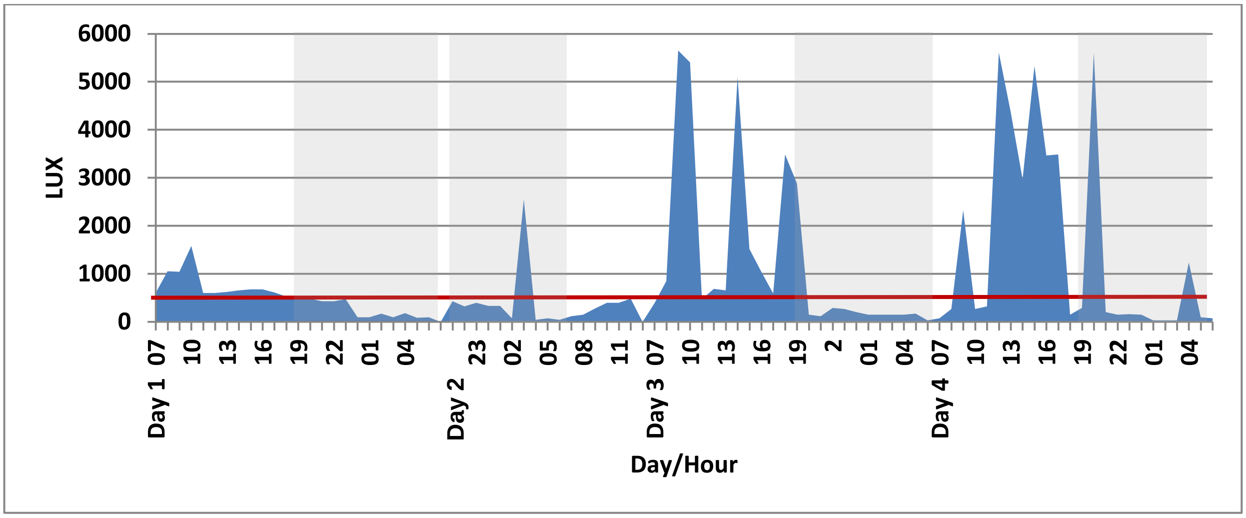
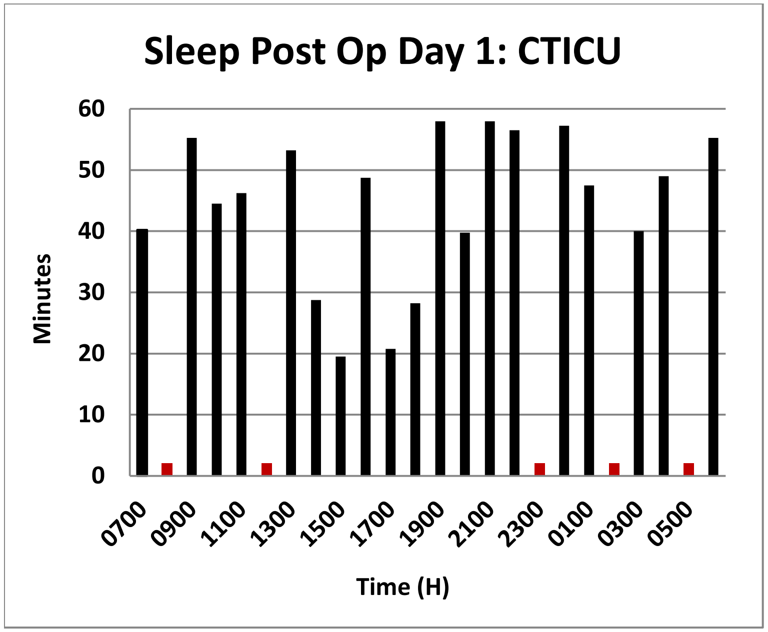
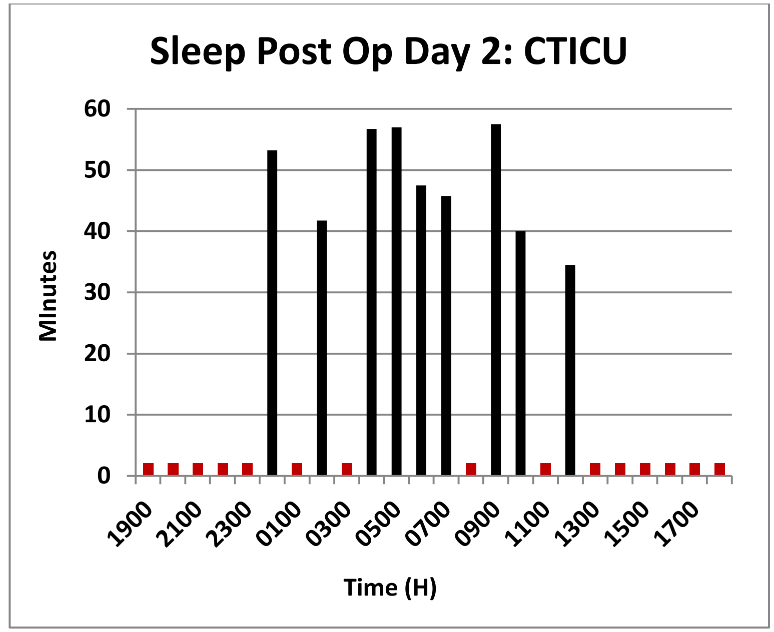
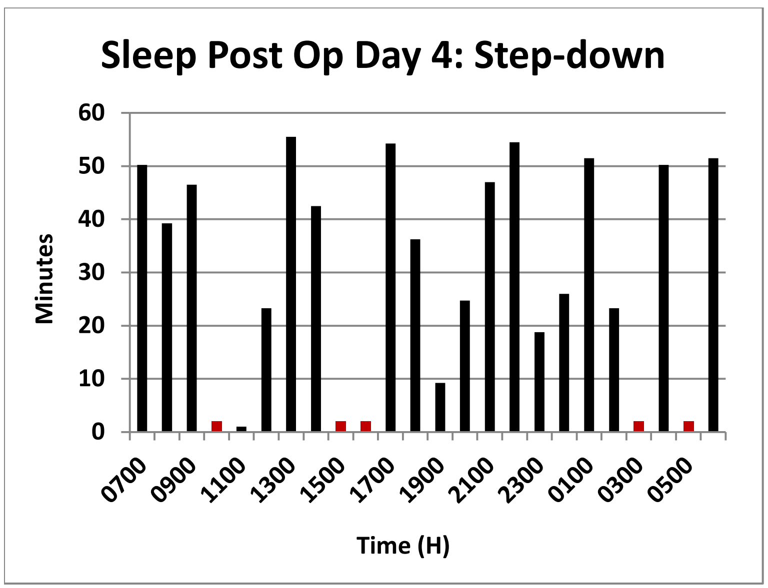


Figure 2. Maximum LUX in each hour over four days of data collection. Days 1 and 2 in the cardiothoracic intensive care unit; Days 3 and 4 in the cardiac step-down unit. Red line indicates recommended maximum exposure of 646 LUX. Shaded areas indicate night hours.


Sleep Post Op Day 1: CTICU
Minutes
0 10 20 30 40 50 60
0700 0900 1100 1300 1500 1700 1900 2100 2300 0100 0300 0500
Time (H)


Sleep Post Op Day 2: CTICU
MInutes
0 10 20 30 40 50 60
1900 2100 2300 0100 0300 0500 0700 0900 1100 1300 1500 1700
Time (H)


Sleep Post Op Day 4: Step-down
Minutes
0 10 20 30 40 50 60
0700 0900 1100 1300 1500 1700 1900 2100 2300 0100 0300 0500
Time (H)

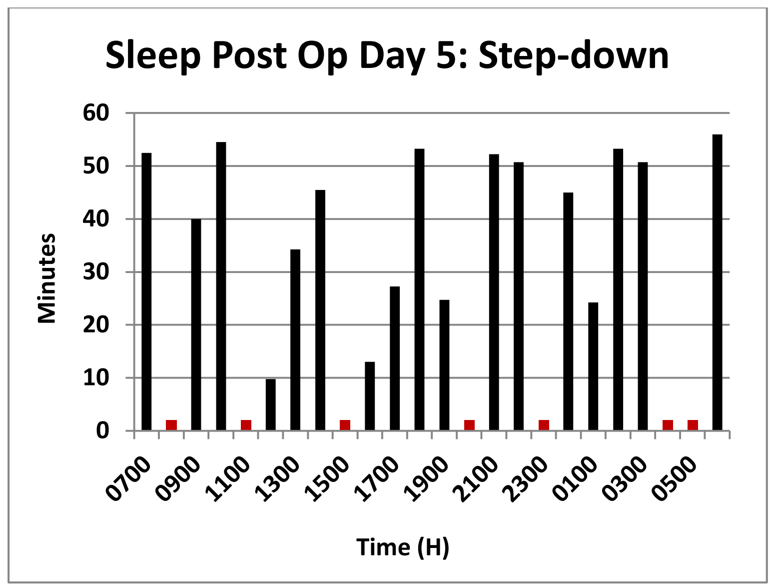

Sleep Post Op Day 5: Step-down
Minutes
0 10 20 30 40 50 60
0700 0900 1100 1300 1500 1700 1900 2100 2300 0100 0300 0500
Time (H)

Figure 3. Sleep in minutes by observation day. Red squares indicate hours excluded from analysis or data not collected (i.e. Day 2).